

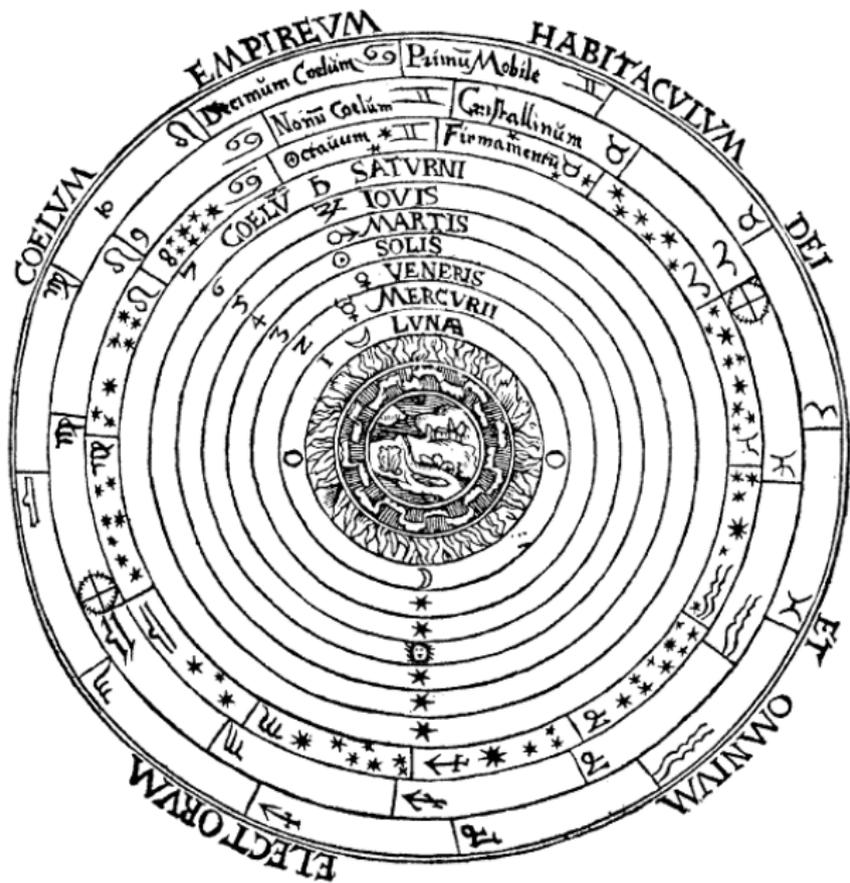
Lecture 19

Copernicus on the Earth's Orbit around the Sun

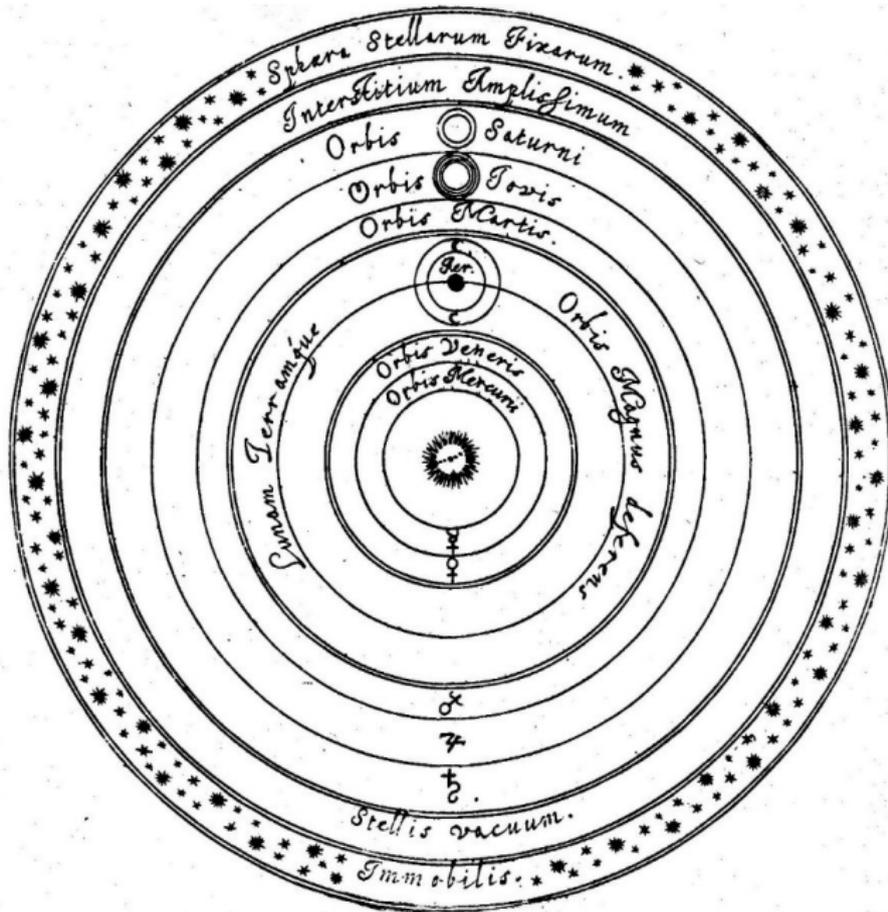
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Scientific Thought I
Fall 2009

Ptolemy's system (from a 16th century book)



Copernicus's system (from a 17th century book)

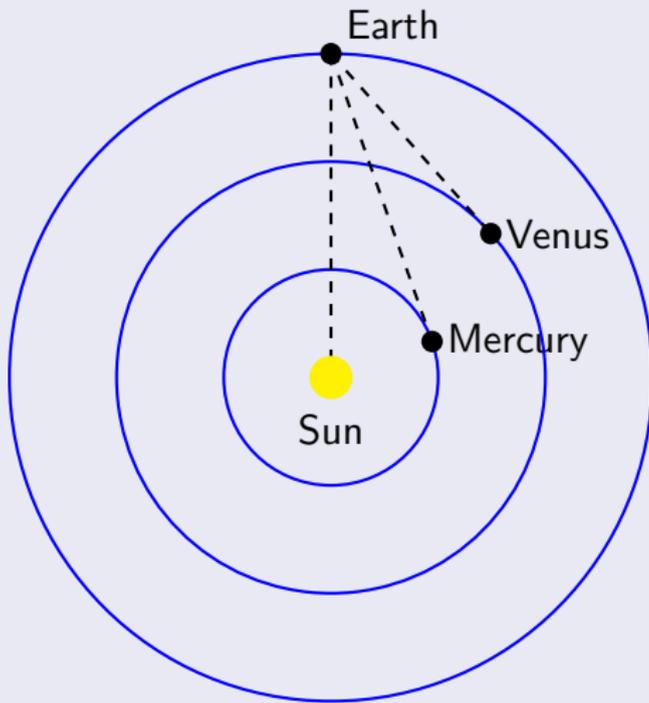


Mercury and Venus always appear close to the Sun

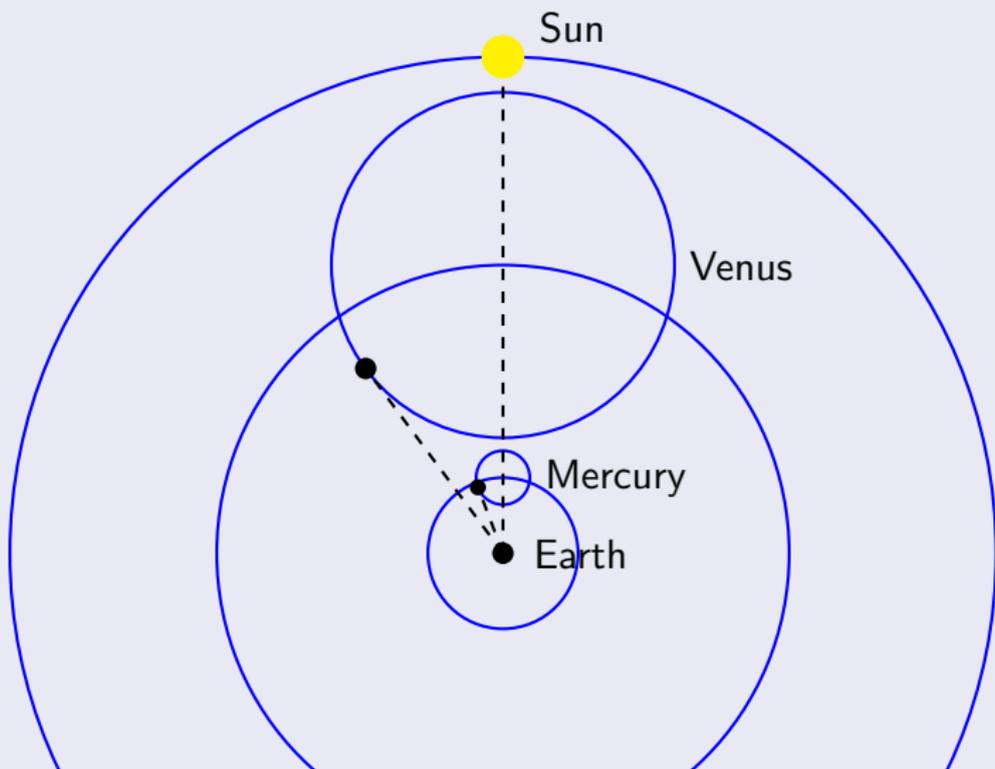
The phenomenon:

- Mercury is never more than 28° from the Sun; Venus is never more than 48° .
- Other planets can be on the opposite side of the sky to the Sun; Mercury and Venus never are.

Copernicus's explanation: Mercury and Venus orbit the Sun with orbits smaller than Earth's.



Ptolemy's explanation: Mercury and Venus orbit Earth with the same period as the Sun but on epicycles.

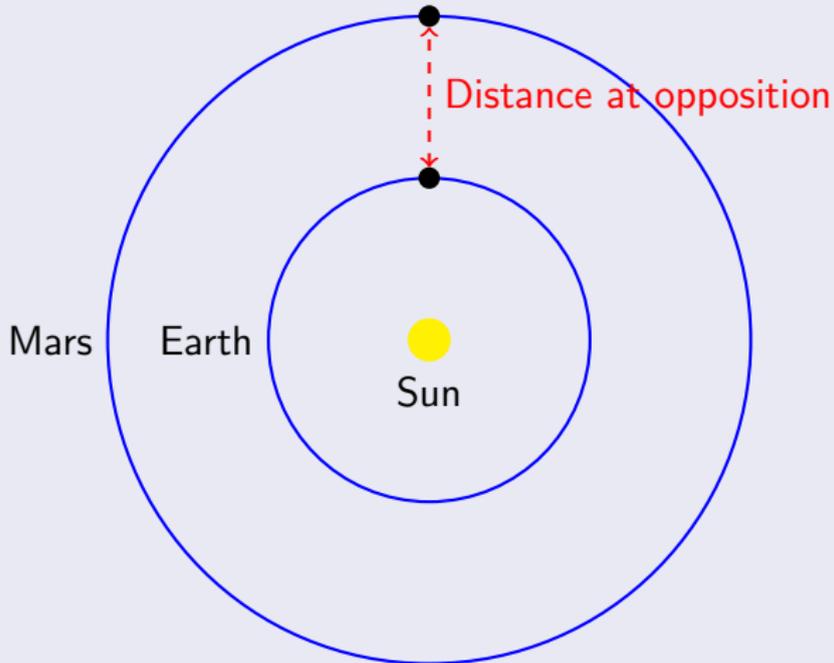


Superior planets are closest when in opposition to the Sun

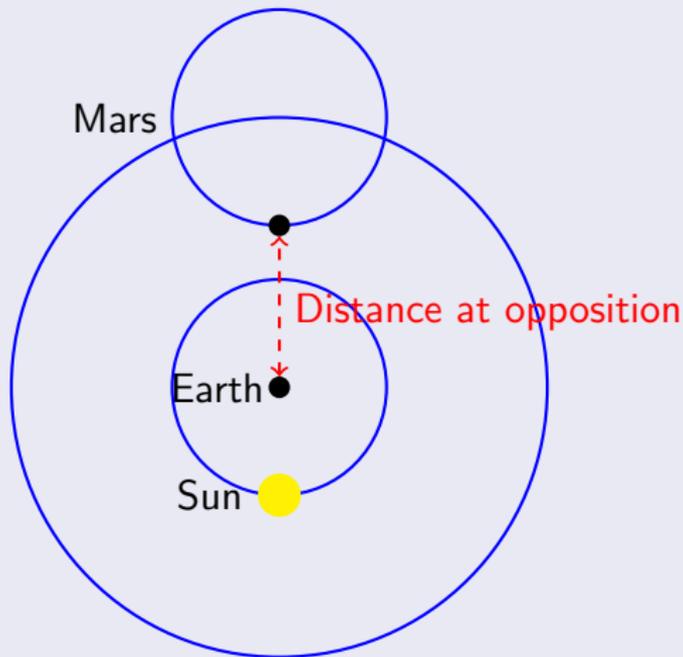
The phenomenon:

- The superior planets are Mars, Jupiter, and Saturn. According to Ptolemy they are above the Sun (i.e., further from Earth than the Sun is).
- A planet is in opposition to the Sun when it is on the opposite side of the sky to the Sun.
- That the superior planets are closest when in opposition is obvious from the fact that they are brightest then.
- *When Saturn, Jupiter, and Mars rise at sunset, they are nearer to the earth than when they set in the evening or appear at a later hour. But Mars in particular, when it shines all night, seems to equal Jupiter in size, being distinguished only by its reddish color. Yet in the other configurations it is found barely among the stars of the second magnitude, being recognized by those who track it with assiduous observations.* [22.21]

Copernicus's explanation: When a superior planet is in opposition to the Sun, Earth is between the planet and the Sun, which minimizes the distance from Earth to the planet.



Ptolemy's explanation: The epicycles of the superior planets rotate so as to bring them closest to Earth when they are in opposition to the Sun.



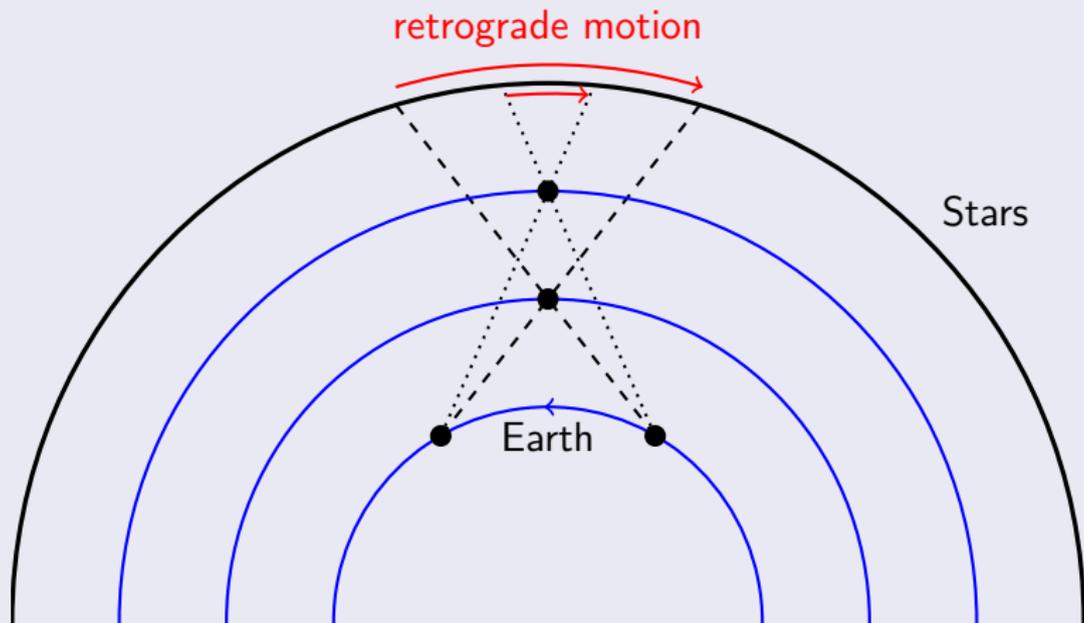
Magnitude of retrograde motion

The phenomenon:

- Planets generally move through the stars from west to east. However, the superior planets occasionally reverse direction and move toward the west for a while; this is called *retrograde motion*.
- Mars retrogrades a greater distance than Jupiter, and Jupiter more than Saturn. (These distances are with respect to the stars.)

Ptolemy's explanation: The epicycles are the right size to produce this result.

Copernicus's explanation: Retrograde motion is an optical illusion caused by Earth overtaking an outer planet. The further away the planet is, the smaller this effect becomes.



Frequency of retrograde motion

- **The phenomenon:** Saturn retrogrades more often than Jupiter, and Jupiter more often than Mars.
- **Copernicus's explanation:** Retrograde motion occurs when Earth overtakes a planet. The further out a planet is, the slower its orbit, and hence the more often Earth overtakes it.
- **Ptolemy's explanation:** The further out a planet is, the faster its epicycle rotates.

Reasons Copernicus thinks his theory better

Simplicity

- Ptolemy needs epicycles, so his theory requires many spheres.
- Copernicus doesn't require as many spheres. For rough agreement with observation, he needs only one sphere per planet.
- *This should be admitted, I believe, in preference to perplexing the mind with an almost infinite multitude of spheres, as must be done by those who kept the earth in the middle of the universe. On the contrary, we should rather heed the wisdom of nature. Just as it especially avoids producing anything superfluous or useless, so it frequently prefers to endow a single thing with many effects.* [20.43]

Harmony

- In Ptolemy's system:
 - Planets orbit the earth from east to west each day but they also move in the opposite direction through the stars. For most planets, this opposite motion is slower the larger their orbit. Hence most planets orbit faster the larger their orbit.
 - Mercury and Venus are exceptions: they stay with the Sun. Ptolemy put them below the Sun. Others put them above the Sun, but still they violate the rule.
- In Copernicus's system, planets orbit faster the smaller their orbit, without exception.
 - Mercury 90 days, Venus 9 months, Earth 1 year, Mars 2 years, Jupiter 12 years, Saturn 30 years.
 - Moon fits because it's closer to Earth than Mercury is to the Sun.

Symmetry

- The Sun is unique in the solar system. It's vastly brighter than anything else and the only body that obviously shines by its own light. So the universe would be asymmetric if the Sun orbited the Earth; it is symmetric if the Sun is at the center.
- The Sun is like a lantern, so the center is an appropriate place for it.
- *In this arrangement, therefore, we discover a marvelous symmetry of the universe, and an established harmonious linkage between the motion of the spheres and their size, such as can be found in no other way. [22.14]*

Questions

- 1 How does Copernicus explain the following facts? How could Ptolemy explain them? Draw diagrams as appropriate.
 - (a) Mercury and Venus always appear close to the sun.
 - (b) The superior planets are closest to the earth when they are in opposition to the sun.
 - (c) The distance traveled in retrograde motion increases in the following order: Saturn, Jupiter, Mars.
 - (d) The frequency of retrograde motion increases in the following order: Mars, Jupiter, Saturn.
- 2 What are the qualities of Copernicus's theory that Copernicus thinks make it more probable that the earth orbits the sun rather than vice versa, as in Ptolemy's theory? Give an example to illustrate each quality that you mention.



Nicholas Copernicus.

On the Revolutions of the Heavenly Spheres.

Johns Hopkins University Press, 1992.

Translation by Edward Rosen.

Numbers in brackets are page and line numbers of this edition.

Text on the web (without page or line numbers).